On the Non-occurrence of Type I X-ray Bursts from the Black Hole Candidates

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Abstract

It has been justifiably questioned that if the Black Hole Candidates (BHCs) have a "hard surface" why Type I X-ray bursts are not seen from them (Nayayan, R., Black Holes in Astrophysics, New J. Phys., 7, 199-218, 2005). It is pointed out that a "physical surface" need not always be "hard" and in could be "gaseous" in case the compact object is sufficiently hot (Mitra, A., The day of reckoning: the value of the integration constant in the vacuum Schwarzschild solution, physics/0504076, p1-p6; BHs or Eternally Collapsing Objects: A review of 90 years of misconceptions, in Focus on Black Hole Research, Nova Sc. Pub., NY, p1-p94, 2006). Even if a "hard surface" would be there, presence of strong strong intrinsic magnetic field could inhibit Type I X-ray burst from a compact object as is the case for Her X-1. Thus, non-occurrence of Type I bursts actually rules out those alternatives of BHs which are either non-magnetized or *cold* and, hence, is no evidence for existence of Event Horizons (EHs). On the other hand, from the first principle, we again show that the BHCs being uncharged and having finite masses cannot be BHs, because uncharged BHs have a unique mass $M = 0$. Thus the previous results that the so-called BHCs are actually extremely *hot*, ultramagnetized, Magnetospheric Eternally Collapsing Objects (ECOs) (Robertson, S. & Leiter, D., Astrophys. J. 565, 447-451, 2002; MECO Model of galactic BH Candidates and active galactic nuclei, in: New Developments in BLack Hole Research, NOva Sc. Pub., NY, p1-p44, 2006) rather than anything else get reconfirmed by non-occurrence of Type I X-ray bursts in BHCs.

1   INTRODUCTION

The concept of BHs arose as Schwarzschild, Hilbert and others tried to find the spacetime geometry around a *MASSENPUNKT*, or a "Point Mass" having

radius $R_0 = 0$ (Mitra, 2005a,b):

$$ds^2 = \left(1 - \frac{\alpha_0}{R}\right) dT^2 - \left(\frac{dR^2}{1 - \alpha_0/R}\right) - R^2 d\Omega^2; \; d\Omega^2 = d\theta^2 + \sin^2\theta d\phi^2 \quad (1)$$

Here α_0 is an *undetermined integration constant*. Both the the interior and exterior spacetime of the BH is, however, represented by the so-called Eddington -Finkelstein metric

$$ds^2 = \left(1 - \frac{\alpha_0}{R}\right) dT_*^2 \pm \frac{2\alpha_0}{R} dT_* dR - \left(1 + \frac{\alpha_0}{R}\right) dR^2 + R^2 d\Omega^2, \quad (2)$$

$$T_* = T \pm \alpha_0 \ln\left(\frac{R - \alpha_0}{\alpha_0}\right); \quad dT_* = dT \pm \frac{\alpha_0}{R - \alpha_0} dR \quad (3)$$

Let us recall now the fundamental property associated with any curvilinear coordinate transformation: $\int \sqrt{-g} \, d^4x = INVARIANT$ where g is the determinant associated with the metric coefficients. Then we can use this property for metrics (1) and (2): $\int \sqrt{-g_*} \, dT_* \, dR \, d\theta \, d\phi = \int \sqrt{-g} \, dT \, dR \, d\theta \, d\phi$. It can be easily verified that $\sqrt{-g_*} = \sqrt{-g} = R^2 \sin\theta$. Then, we will have, $\int R^2 \, dT_* \, dR \, \sin\theta \, d\theta \, d\phi = \int R^2 \, dT \, dR \, \sin\theta \, d\theta \, d\phi$. If we first carry out the θ and ϕ integrations on both sides of this Eq., we will obtain $\int R^2 \, dT_* \, dR = \int R^2 \, dT \, dR$. Then by using the form of dT_* from Eq.(3) in the above equation:

$$\int R^2 \, dT \, dR \pm \alpha_0 \int \frac{R^2}{R - \alpha_0} \, dR \, dR = \int R^2 \, dT \, dR, \quad or, \quad (4)$$

$$\alpha_0 \int \frac{R^2}{R - \alpha_0} \, dR \, dR = 0 \quad (5)$$

This equation can be satisfied only if $\alpha_0 = 2M_0 \equiv 0$(Mitra, 2005a). Thus the uncharged Schwarzschild (actually Hilbert) BHs have the unique mass $M = M_0 = 0$. Hence, though, *mathematically, BHs do exist*, their mass, $M_0 \equiv 0$. However, mathematically, there could be charged BHs with $M \equiv Q$; but astrophysical BHs are necessarily uncharged. And since the (uncharged) BH paradigm was built by assuming $\alpha_0 = 2M_0 > 0$, it collapses instantly. Moreover, since the observed BHCs (or anything else in the universe) have $M > 0$, they cannot be (uncharged) BHs! It is important to note that Eq.(3) is obtained by integrating Eq.(1) from $R = 0$ to $R = R > R_0$, and, incase, we are considering a body with finite radius R_0, its *interior solution is not covered by Eq.(1)*, and hence Eddington-Finkelstein metric is *not valid in such a case*. Consequently, the procedure adopted here would be irrelevant in such a case and one would indeed have $\alpha_0 \to \alpha = 2M > 0$. Mathematically while $M = \int_0^{R_0} 4\pi R^2 \, \rho \, dV > 0$ for density $\rho > 0$ and radius $R_0 > 0$, its value for a "massenpunkt", i.e., in the limit $R_0 \to 0$, is $M_0 \equiv 0$.

2 NON-OCCURRENCE of TYPE I BURSTS

As collapse of massive stars proceeds beyond the *cold* Neutron Star (NS) stage having a small surface gravitational redshift $z_0 = 0.2 - 0.3$ and crosses the $(1 + z_0) = \sqrt{3}$ limit, it is believed to hurtle towards the BH stage having $z_0 = \infty$. If so, a very important physical phenomenon would occur. At high z_0, photons/neutrinos generated within the body move along highly curved paths and the chance of escaping decreases as $\sim (1 + z_0)^{-2}$. Density of radiation (ρ_r) increases within the collapsing body because of of both gravitational trapping and matter-radiation interaction (diffusion) induced trapping of radiation. It has been shown recently that because of such effects, $\rho_r/\rho_0 \sim z_0 \gg 1$ (Mitra, 2006a). Since BH formation requires $z_0 \to \infty$, the collapsing object becomes almost a pure ball of radiation *even before the formation of an EH*. Note, in the usual collapse folklore, the Equation of State of the collapsing object would remain practically unchanged and $\rho_r/\rho_0 \ll 1$ before formation of any EH. Consequently, in this folklore, one would promptly find a BH of the mass of the original star core. But what actually happens is that as the trapped radiation pressure would attain its corresponding Eddington value, the outward radiation/ heat outflow pressure would dynamically stop the collapse. The object then becomes a " Relativistic Radiation Pressure Supported Star" (Mitra 2006b) having a radius $R \approx 2M$ and $z_0 \gg 1$. In a strict sense, the object is radiating and contracting, and since this process becomes eternal, it is called an "Eternally Collapsing Object" (ECO). There is practically no chance that the hot collapsing object would mysteriously turn into a cold scalar field or a "Dark Energy Star". As, $z_0 \to \infty$ (BH), asymptotically, for an ECO, $M \to M_0 = 0$.

It has been specifically shown that, the BH candidates have strong intrinsic magnetic field by virtue of their physical surface which in turn has shown that BHCs *do not have any Event Horizon* (Robertson & Leiter, 2002, 2005). Accordingly, they are likely to be ECOs rather than anything else. But Narayan (2005) and his coworkers have repeatedly raised the valid question - if the BHCs have a "surface", why they do not entertain Type I X-ray bursts. It is forgotten here that, even if the BHCs would possess a real "hard surface" Type I burst activity would be suppressed in the presence of a strong surface magnetic field because of (a) Modification of Scattering Cross-sections, and (b) Strong magnetic channeling of the accretion flow on tiny hot-spots. This is the reason that an accreting X-ray pulsar such as Her X-1 does not show any Type I X-ray burst, and if the argument of Narayan would be taken seriously, the pulsar in Her X-1 would have an "Event Horizon". Thus the ECOs with strong intrinsic magnetic fields, would not show any Type I burst activity. Hence the argument of Narayan, at best, rules out the exotic *cold* BHCs and further consolidates the idea of ECOS as the BHCs. In reality, the stellar mass ECOs are extremely hot with local temperature exceeding 200 MeV and they

could be in a state of Quark Gluon Plasma (Mitra, 2006b). Thus although, ECOs will have a physical surface, they have no "hard surface". Any nuclear matter accreted onto a MECO may turn into QGP or get lost in the existing sea of QGP. The question of any Type I X-ray burst would not arise in this scenario.

There could be circumstantial evidences that the BHCs are not BHs: (1) Many BHCs do exhibit occurrence of ultra-relativistic jets, and, though no EH has ever been detected, it was generally believed that somehow *mysteriously* and self-contradictly, such jets must be associated with EHs (when "nothing can escape from an EH"). However, the compact object in Cir X-1, has a physical surface and has been found to launch an ultra relativistic jet with bulk $\Gamma > 10$ (Fender et al., 2004). Similarly, all ultrarelativistic jets may actually be associated with compact objects having physical surfaces. In general, presence of an intrinsic magnetic field may be necessary for both launching and collimation of jets. In fact, we know with certainty that there are objects without any EH but intrinsic magnetic field; and often they do launch jets: e.g., protostellar clouds, stars, Neutron Stars etc. In contrast, not a single case is known with certainty, where an object with an EH and without any intrinsic magnetic field has ever launched a jet because an EH has never been be detected! (2) As discussed (Van der Klis, 2006), the essential low freq. QPO behaviour of NSs and BHCs is the same. The difference in the high freq. range may be due to stronger B and z of BHCs. (3) The large kick velocities associated with BHC binaries cannot be explained if the BHCs are really BHs which are formed by direct gravitational collapse(Van den Heuvel, 2006) because prompt formation of finite mass BH is supposed to be a quiet affair accompanied by the prompt formation of an EH . On the other hand, such large kick velocities can be easily understood if the BHCs are objects with physical surfaces (but HOT) and formed in events similar to powerful supernovae (Gamma Ray Bursts) whose ν-luminosity could be 100 times more than for typical SN events.

References

Fender, R., Wu, K., & Helen, J. et al., An ultra-relativistic outflow from a neutron star accreting gas from a companion, *Nature*, 427, 222-224 (2004)

Mitra, A., The Day of Reckoning: the Value of the Integration Constant in the Vacuum Schwarzschild Solution, physics/0504076, p1-p6, 2005

Mitra, A., BHs or ECOs: A Review of 90 Years of Misconceptions, in *Focus on Black Holes Research*, p1- p94, (Nova Science Pub., NY, 2005)

Mitra, A., A Generic Relation Between Baryonic and Radiative Energy Densities of Stars, MNRAS Lett., 367, L66-L68, 2006 (gr-qc/0601025)

Mitra, A., Radiation Pressure Supported Stars in Einstein Gravity: ECOs, MNRAS, 369, 492-496, 2006, (gr-qc/0603055)

Narayan, R., Black Holes in Astrophysics, New J. Phys, 7, 199-218, 2005

Robertson, S and Leiter, D., Evidence for Intrinsic Magnetic Moment in Black Hole Candidates, Astrophys. J., 565, 447-451, 2002 (astro-ph/0102381)

Robertson, S. and Leiter, D., MECO Model of Galactic Black Hole Candidates and Active Galactic Nuclei, in "New Developments in Black Hole Research", p1-p44, (Nova Science Pub., NY, 2005), (astro-ph/0602453)

Van den Heuvel, E.P.J., Advan. Sp. Res. (in press), 2006

Van der Klis, M., Advan. Sp. Res. (in press), 2006